

COMPARISON OF AVAILABLE METHODS FOR PREDICTING
MEDIUM FREQUENCY SKY-WAVE FIELD STRENGTHS

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The chronological development of the available methods for predicting medium frequency sky-wave field strengths is presented with a brief discussion of each method. Measured field strengths for 36 medium frequency sky-wave paths are compared with the predicted field strengths from several different prediction methods. Based on the rms errors between observations and predictions, the 1938 Cairo Curves provide the best estimates of the sky-wave field strengths for very long paths worldwide. A new prediction method developed for use in North and South America only, provides improved estimates of the sky-wave field strengths for paths <3500 km.

Key words: CCIR; Cairo Curves; FCC Curves; medium frequency; radio propagation predictions; skywaves

1. INTRODUCTION

Since the inception in the early 1920's of medium frequency (MF) AM broadcasting, the steadily increasing demand for stations resulted in a congestion of the medium frequency spectrum by the late 1940's. The need for more precise and detailed information concerning sky-wave propagation of MF radio waves has been mentioned in various sources since World War II (Phillips, 1950; JTAC, 1964). Today, because there is still a demand for an increase in the number of broadcast services, various proposals are being explored to improve the efficiency of this portion of the spectrum and provide for an orderly expansion of broadcast services. However, an increase in broadcast services could also result in substantial interference to adjacent and co-channel stations and reduce the service areas of currently operating stations.

In view of these problems, the International Radio Consultative Committee (CCIR) of the International Telecommunication Union (ITU) has scheduled a Regional Administrative MF Broadcasting Conference (Region 2). The first session of the Conference was held in Buenos Aires in March, 1980, to establish a basis for preparing a frequency assignment plan for the MF broadcasting band in Region 2 (North and South America). This first session considered propagation data, modulation standards, channel spacing, protection ratios including noise levels, required field strengths, transmitting antenna characteristics,

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transmitter power, and planning. The second session, to be convened in November 1981, will draw up an agreement and an associated frequency plan of assignments in the MF broadcasting band in Region 2.

Accurate and reliable technical criteria are needed to support the activities in the second session of this conference. This report is concerned with only one technical aspect; i.e., the reliability of existing methods for predicting long-distance propagation of MF radio waves at night. Several prediction methods are available for this purpose. A brief review of these methods and a comparison between measured field strengths and predicted field strengths for some of the methods are presented here.

2. CHRONOLOGICAL DEVELOPMENT OF MF FIELD STRENGTH PREDICTION METHODS

This section presents the various MF field strength prediction methods and their revisions in the chronological order of their documentation.

1938. One of the earliest recognized field strength prediction techniques was the so-called "Cairo Curves." Two curves, one for North-South and one for East-West propagation were adopted by the CCIR at the International Radiocommunications Conference, Cairo, 1938. At the CCIR VIIth Plenary Assembly, Warsaw, 1956, the International Frequency Registration Board (IFRB) requested CCIR to extend the Cairo Curves to include variations with magnetic latitude, season, and solar activity. However, it was not until 1974 that CCIR recommended a more precise, accurate, worldwide method for predicting MF field strengths, presumably as a replacement for the Cairo Curves.

1946. The U.S. Federal Communications Commission (FCC), in connection with their Clear Channel Hearing, Docket #6741, presented a set of composite curves showing propagation losses for nighttime sky-wave field strengths in North America. They were incorporated in the FCC Rules and Regulations, Part 3, Radio Broadcast Services.

1959. Norton (1959) developed an MF sky-wave field strength prediction method based on a physical model which corresponds to a wavehop treatment.

1963. The CCIR Documents of the Xth Plenary Assembly, Geneva, presented an empirical formula and a set of curves developed by the European Broadcasting Union (EBU) for determining the annual median value of the nighttime field strength for MF for the European Broadcasting Area (Ebert, 1962).

1966. Barghausen (1966) modified Norton's semi-empirical formula for estimating polarization and absorption losses.

1966. The CCIR Documents of the XIth Plenary Assembly, Oslo, formally recommended the provisional use of the EBU formula for the European Broadcasting Area and also presented a modification to the EBU formula to provide predictions of short-distance sky-wave field strengths for the African LF/MF Broadcasting Conference, Geneva, 1966.

1970. The CCIR Documents of the XIIth Plenary Assembly, New Delhi, presented a separate formula for estimating the annual median field strengths for distances <300 km.

1971. Olver et al. (1971) developed a prediction method based on a wavehop approach similar to that of Norton (1959) except that a ray trace procedure is used.

1973. Knight (1973) proposed a manual method of approximating the wavehop method of Olver et al. (1971).

1974. The CCIR Documents of the XIIIth Plenary Assembly, Geneva, included an empirical formula developed by the U.S.S.R. for estimating the dependence of field strength on frequency and distance at a geomagnetic (dipole) latitude of 37° for the U.S.S.R., and a worldwide semi-empirical method based on physical principles proposed by the U.K.

The CCIR Interim Working Party (IWP) 6/4 modified the U.S.S.R. method by incorporating certain features of the U.K. method and recommended the provisional use of the modified U.S.S.R. method for predicting MF sky-wave field strengths worldwide.

1975. The Final Acts of the Regional Administrative LF/MF Broadcasting Conference (ITU, 1975) adopted the CCIR, Geneva, 1974, sky-wave field strength prediction method (150 to 1600 kHz) for Region 1, Australia and New Zealand. For the Asian part of Region 3, North of 11°S, the "Cairo" North-South curve with a modification for polarization coupling loss (L_p) was recommended.

1977. Wang (1977) developed a new MF sky-wave field strength prediction method for North America.

1978. The CCIR Documents of the XIVth Plenary Assembly, Kyoto, further modified the CCIR, Geneva, 1974, sky-wave field strength prediction method for MF (150 to 1600 kHz) and recommended its provisional use worldwide (CCIR, 1978). Several sky-wave field strength prediction methods proposed for various parts of the world also were described. They are:

- 1) Cairo North-South curve adopted for use in Asian part of Region 3 - mathematical approximation presented.

2) EBU method to be used in European Broadcasting Area with separate formula for distances <300 km.

3) U.S.S.R. method - valid between 37° and 60° geomagnetic latitude for distances up to 6000 km and has no frequency dependence.

4) U.K. method - valid for all distances worldwide except for the auroral zones and has no frequency dependence.

5) Wang's 1977 method given as an alternative method for the U.S. 1979. Wang (1979) proposed a modification of the CCIR Kyoto 1978 method to improve accuracy in Region 2.

1979. The Inter-American Conference on Telecommunications extended the FCC median signal level curve to distances beyond 4300 km using the Cairo North-South Curve and recommended its adoption for Region 2.

3. DISCUSSION OF THE METHODS

In this section, a brief description and mathematical formulation, where applicable, is given for the methods which have been used internationally and for some of the methods that appear to be more scientific approaches but have not been widely applied.

3.1 Cairo Curves

The Cairo Curves (Figure 1) were based on three measurement campaigns conducted by the International Broadcasting Union (IBU) in the northern hemisphere winters of 1934/35, 1935/36, and 1936/37. As many countries had taken measurements on paths up to 2000 km and obtained results that were in close agreement with the propagation curves for similar distances drawn by Dr. van der Pol's committee at Madrid, 1932, and adopted by CCIR, Lisbon, 1934, these campaigns involved paths ranging from 5000 to 11900 km and frequencies between 695 and 1185 kHz. Measurements were made on 23 paths between North America and Europe, North America and South America, and South America and Europe; the great circle paths are shown in Figure 2. For the third campaign, the transmitting stations were selected on the basis of the following considerations: 1) transmitter power (50 to 120 kW), 2) half-wavelength antennas, and 3) frequencies relatively close to 1000 kHz (Knight, 1977). In Figure 1, the North-South curve represents transequatorial propagation, and the East-West represents propagation at high latitudes. The original curves were in terms of the quasi-maximum value for 1 kW radiated, versus distance. This was defined at the Madrid conference as the value exceeded not more than 5% of the time